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Abstract

OPTIMALIZATION OF THE INITIAL CONVERSION RATIO OF A NUCLEAR
REACTOR CONSIDERED AS A GAMES THEORY PROBLEM

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It is shown that the problem of obtaining a maximum initial conversion ratio (by non-homogeneous spatial distribution of the fissile material), together with minimum fuel consumption, has the structure of a two-matrix game with a non-zero sum.

The volume of the reactor is regarded as being divided into q separate, indeterminate volumes, each containing $U_i = \mu_i U$ fertile nuclei and $P_i = \xi_i P_c$ fissile nuclei, where U is the total number of fertile nuclei and P_c is the number of fissile nuclei necessary for critical mass.

These conditions of maximum density and criticality make it possible to determine the geometrical structure and the value of P_c for a given U and a given distribution (μ_i, ξ_i) .

The number of fissile nuclei produced in a reactor in unit time is

$$K_1 = \sigma_u^{cp} \cdot \sum_{i=1}^q \mu_i \cdot \phi_i^-$$

and the number of fissile nuclei disappearing is

$$K_2 = \sigma_p^a \cdot p \cdot \sum_{i=1}^q \xi_i \cdot \phi_i^-$$

where σ_u^{cp} is the cross-section of the process leading to the appearance of a fissile nucleus, σ_p^a the cross-section of the process leading to the disappearance of a fissile nucleus, ϕ_i^- the mean neutron flux in the region i , and $p = P_c/U$.

The gain K_1 and the loss K_2 of fuel are functions of the distribution (μ_i, ξ_i) adopted and of U .

The ratio K_1/K_2 is the breeder ratio of a breeder reactor.

Let us assume two players, one possessing U fertile nuclei and adopting the distribution μ_i^k , the other adopting the distribution ξ_i^e of P_0 fissile nuclei.

The gain of the first is given by the terms of the matrix $K_1(\mu_i^k, \xi_i^e)$ and the loss of the second is given by those of the matrix $K_2(\mu_i^k, \xi_i^e)$. The first is therefore interested in choosing the μ_i^k distribution which makes K_1 a maximum for any μ_i^e distribution chosen by the second. The second will choose the ξ_i^e distribution making K_2 a minimum for any μ_i^k distribution chosen by the first.

The problem thus corresponds to the structure of a two-matrix game with a non-zero sum $\Gamma(K_1, K_2)$.

For fast neutron breeder and two-region thermal reactors, an analysis is made of the information that can be obtained by studying the strategy of the game.